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FIXED CELL COMMUNICATION SYSTEM WITH REDUCED INTERFERENCE

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Technical Field

The present invention relates generally to communications systems, and more particularly, to preventing interference in fixed cell systems .

Background Art

In this communication age, content providers are increasingly investigating ways in which to provide more content to users as well as interfacing with a larger group of users. The latest communications systems use digital broadcast satellites to broadcast information to users.

In addition to satellites, stratospheric platforms are currently under development. Stratospheric platforms may be unmanned vehicles that can fly for several months at a height of about 60,000 feet such as a solar powered electric plane that is modular in design and may be configured to carry a variety of payloads. Stratospheric platforms have numerous advantages over geostationary satellites, including that a large bandwidth density can be projected over a small but populated area, associated transmission delays are significantly reduced, the power required for transmitting and receiving is substantially smaller, and the user elevation are higher in general. Also, these stratospheric platforms can be deployed relatively rapidly compared to satellites and thus, if a business need increases, the system capability may be increased quickly through deploying new platforms.

Commonly, such communication systems have a high altitude communications device such as a satellite or a stratospheric platform as described above. Also, such systems have user terminals and a gateway station or plurality of

gateway stations that communicate with the high altitude communications device and link the user terminals to terrestrial networks.

Because the frequency resources are scarce for over-air transmissions, various multiplexing schemes are used to provide a greater number of communication signals within an allocated communication ban. Such schemes include code division multiple access ("CDMA"), time division multiple access ("TDMA"), frequency division multiple access ("FDMA"), or combinations of these schemes. In addition to the multiplexing schemes, various polarizations may be used to increase system resources.

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In a fixed cell structure, beams having different system resources such as frequencies or polarizations are directed to fixed cell. However, due to the antenna structure and the nature of a beam, side lobes from the beam may interfere with communications in cells having the same communication characteristic such as frequency and polarization. To reduce side lobes and achieve a high peak antenna directivity and low side lobes, the antenna aperture is commonly enlarged. A tradeoff may occur if the antenna aperture size is fixed and thus the side lobe characteristic may be sacrifice for a lower main lobe directivity. The drawback to a large aperture is the higher payload mass associated therewith. A low main lobe to side lobe ratio also implies a reduce number of users of the system.

It is typically a goal of communication system designers to reduce mass and increase the number of potential users without increasing the mass or size of the system. It would therefore be desirable to meet these goals without increasing interference between beams.

Summary Of The Invention

It is an object of the invention to provide a communication system having a high main lobe to side lobe ratio in a selected areas to reduce interference with other beams using the same system resources such as frequency and polarization.

In one aspect of the invention, a communication system has a high altitude communication device having an antenna for generating a first plurality of beams. Each of the plurality of beams has a first frequency resource, a plurality of main lobes directed to one of a first plurality of cells, and a plurality of side lobes. The high altitude communication device generates a second plurality of beams having a second resource directed to one of a second plurality of cells. The antenna is formed so that the side lobes of the first plurality beams are selectively suppressed in the first plurality of cells having said first resource.

In a further aspect of the invention, a method of operating communication system comprises the steps of:

generating a fixed reuse pattern in a service area from a high altitude communications device, said pattern having at least a first resource cell and a second resource cell;

selectively suppressing a side lobe of a beam having a first resource so a non-side lobe suppressed portion aligns with a cell having said second resource.

One advantage of the invention is that by implementing the present invention, the spacecraft weight does not have to be increased.

Other objects and features of the present invention will become apparent when viewed in light of the detailed description of the preferred embodiment when taken in conjunction with the attached drawings and appended claims.

Brief Description of the Drawings

Figure 1 is a system level view of the communication system according to the present invention.

Figure 2 is reuse plot of a cell coverage map illustrating cells having four communication resources.

Figure 3 is a reuse plot of the cell coverage of Figure 2 from the communication device perspective.

Figure 4 is a plot illustrating various beams having the same frequency as a central beam.

Figure 5 is the plot of Figure 4 with the addition of a radiation pattern formed according to the present invention for the central beam.

Figure 6 is a plot illustrating multiple beams with a radiation pattern for an off-center beam formed according to the present invention.

Figure 7A is a prior art contour plot illustrating an antenna having side lobe interference.

Figure 7B is a contour plot of an antenna having main lobe portions and side lobe portions formed according to the present invention.

Best Modes For Carrying Out The Invention

In the following description, the same reference numerals are used to identify the same components in the various views. Those skilled in the art will recognize that various other embodiments, structural changes and changes in exemplary measures may be made without departing from the scope of the invention. The following examples use transmitted beams, however, those skilled in the art will recognize the antenna gain patterns are applicable for both transmit and receive mode.

Referring now to Figure 1, a communications system 10 has a cell pattern 12 that is illustrated as a plurality of hexagons on the earth's surface. The hexagons represent the footprint of a radiated beam onto the earth's surface. These are otherwise known as cells 14. Each cell 14 represents a geographic area that can receive signals from the stratospheric platform with a pre-determined signal strength. A plurality of user terminals 16 are used to illustrate fixed users. Each user terminal 16 may receive a signal with the predetermined signal strength within a spot beam in a multiple spot beam pattern radiated from a communications payload of a high altitude communication device 18.

Communication system 10 further includes a gateway station 20 that is coupled to terrestrial networks 22. Communication system may also include a device operations center 24. Both gateway station 20 and device operations center 24 are in communication with high altitude communication device 18. Gateway

station 20 provides connectivity between user terminals 16 and terrestrial networks 22 through high altitude communications device 18. Device operation center 24 provides command and control functions to communications device 18. Although illustrated as two separate units, gateway station 20 and device operation center 24 may be combined into the same physical location.

The communication signals between high altitude communication device 18 and user terminals 16 may be referred to as user links 26. User links 26 represent the transmit and receive beams from user device 16 and high altitude communications device 18. A feeder link 28 is defined between high altitude communications device 18 and gateway station 20.

High altitude communications device 18 is an unmanned vehicle that can fly for several months at an altitude of about 60,000 feet above the earth. Stratospheric platform may be an unmanned vehicle that is a solar-powered, electric plane that is modular in design and may be configured in a variety of ways. The stratospheric platform is operated through the device operations center 24 to fly in a small radius flight path over a given spot on the earth.

High altitude communications device 18 is used as a communication node for gateway station 20 and user terminals 16, each of which has a medium gain antenna with a small beam-width that is pointed at the direction of the high altitude communications device 18. Although only one gateway station 20 is illustrated in the figure, those skilled in the art would recognize that various numbers of gateway stations may be employed. As will be further described below, gateway station 20 has a high gain antenna with very small beam width that may need a tracking mechanism to maintain a communication link with high

altitude communication device 18 throughout the flight path. These antennas may be electronically or mechanically steered.

High altitude communication device 18 has a payload 30 that is used to connect user terminals 16 and gateway station 20. High altitude communication device 18 has an antenna 32 or plurality of antennas that are used to generate and receive beams from user terminals 16 and gateway station 20. As will be further described below, the beams have a main lobe that is directed to a particular cell for communicating therewith. Due to the physical nature of antennas each main beam has parasitic side lobes having an amplitude substantially less than the main lobe but extend outside the intended cell.

Referring now to Figures 2 and 3, a plan view of a cell reuse pattern 12 illustrated having cells 14 in Figure 2 from the ground perspective. Figure 3 illustrates the plan view of the cell reuse pattern 12 from the communication device perspective. Figures 2 and 3 illustrate a FDMA system with four different frequencies illustrated as four differently cross-hatched areas. This is called a four-beam frequency reuse pattern. Those skilled in the art will recognize that various numbers of frequencies may be used, such as three-beam or 7 beam frequency reused pattern. As illustrated, the entire frequency spectrum is subdivided into four frequency bands. Cells 14A have one frequency band. Cells 14B have a second frequency band. Cells 14C have a third frequency band. And, cells 14D have a fourth frequency band. Each cell belongs to one of either 14A, 14B, 14C or 14D as symbolized by the different cross-hatching. As mentioned above, this invention applies equally to orthogonal code in place of frequency band. A plurality of gateway stations 20A, 20B, 20C, 20D and 20E are illustrated.

Referring now to Figure 4, a plot in degrees from a high altitude communication device is illustrated. This plot is a simplified version of Figure 3 illustrating only the beams having the same resource as those of 14A of Figure 3. As shown, a central beam 34 is illustrated.

Referring now to Figure 5, the plot of Figure 4 is illustrated having the central beam 34 being optimized to prevent interference with other non-central beams 14A. A plurality of lines extending annularally around central beam 34 illustrate the gain change in decibels from the center of the center beam 34. As can be seen, annular ring 36A illustrates a –4.0 decibel drop from the center. Annular ring 34B represents a -10 dB drop from the center. Annular ring 34C represents a –20.0° dB drop from the center. Line 34D represents a –30 dB drop from the center. As can be best seen by the –20.0° dB drop, the antenna of the high altitude device has been manipulated to allow the side lobe interference from the center beam to extend between the adjacent beams 14A. Also, the interference also extends between and around the beams 14A.

Referring now to Figure 6, non-central beam 38 with annular rings 40 representing the gain drops from the non-central beam 38 is illustrated. In this figure, ring 40A represents a –2.0 dB drop from the center of non-central beam 38. Ring 40B represents a –4.0 dB drop from the center of non-central beam 38. Ring 40C represents a -10 dB drop from the center of non-central beam 38. Ring 40D represents a -20 dB drop from the center of non-central beam 38. Line 40E represents a –30 dB drop from the center of non-central beam 38. As can be seen, suitable side lobe interference is formed by selectively tailoring the shape of the reflector to suppress interference with beams 14A having the same communication characteristics such as frequency, polarization, code, etc.

In operation, advantageously, the present invention is capable of achieving high main lobe to side lobe ratio while maintaining peak directivity by shaping the antenna to generate beams to prevent interference with the side lobes of beams using the same communication resource. At the same time, the portions of the beam that do not have the same communication resource are not suppressed. This enables the use of a relatively smaller aperture than those that would ordinarily be used. This allows the payload of the high altitude communication device to not increase due to having to provide a larger antenna aperture. By relaxing requirements on the side lobe, better main lobe performance may be achieved with an antenna design that requires side lobe suppression for all beams. The shape of the antenna changes depending on the specific geometries of the communication system 10. That is, the distance between the beams having the same frequency resource may vary depending on the system and the number of resources used.

Referring now to Figures 7A and 7B, a side view of an antenna 31 of the prior art and an antenna 32 is illustrated. Preferably, a main lobe portion 50 is first formed so that main lobes of the beams are directed to the desired location. Thereafter, the side lobes portions 52 are formed so that the side lobes are selectively directed to reduce interference with beams using the same resource.

In Figures 3 through 5, a four-color reuse pattern is illustrated. However, the present invention applied equally to other numbers such as a seven-color reuse or various other reuse patterns as would be known to those skilled in the art. These parameters change the distance required for side lobe suppression because the distance between adjacent beams is changed. If fixed frequency reuse pattern allows the system capacity to be maximized. Interference locations may be experimentally determined directly or using computer simulation. The interference

locations are identified and the antenna is shaped to suppress the side lobes where interference locations occur. Interference locations are areas where the side lobe may overlap the beams having the same characteristics. In Figure 6, the potential interference locations are illustrated by area 42. Of course, the interference locations are highly dependent on the initial antenna configurations and the frequency reuse configuration. The antenna is reshaped to suppress interference at locations 42.

While particular embodiments of the invention have been shown and described, numerous variations alternate embodiments will occur to those skilled in the art. Accordingly, it is intended that the invention be limited only in terms of the appended claims.